U.S. Coast and Geodetic Survey
Geodesy

rial No. 111

DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

E. LESTER JONES, SUPERINTENDENT

GEODESY

NERAL INSTRUCTIONS FOR PRECISE AND SECONDARY TRAVERSE

U. S. COAST AND GEODETIC SURVEY

Special Publication No. 58

PRICE, 10 CENTS

old only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
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GENERAL INSTRUCTIONS FOR PRECISE AND SECONDARY TRAVERSE, U. S. COAST AND GEODETIC SURVEY.

INTRODUCTION.

During the early part of 1917 the United States Coast and Geodetic Survey started work on a system of precise traverse lines in Georgia and Florida, which have since been extended into other States along the Atlantic coast. This work was called for by the Corps of Engineers of the United States Army to give the necessary primary control for various military maps in that section of the country. Traverse was used instead of triangulation as the general lay of the land and the prevalence of high timber would have made high scaffold signals necessary to give clear lines for triangulation. The traverse lines followed the railroads, and so required but little signal building or cutting of timber.

Although traverse has been used in place of triangulation by the United States Coast and Geodetic Survey at various times in the past it has never been used on so large a scale as in the recent work. The methods employed in the work were largely experimental at first, but they have been gradually changed and improved until they have become practically standard.

It has been thought advisable to publish these general instructions in order to preserve the knowledge that has been gained, to standardize any future field work as much as possible, and to prevent the continued use of any methods which have been found inefficient or unwise.

When a precise traverse is to be run over country roads or along beaches, separate instructions supplementing these general instructions will be issued to the officer in charge of the general operations.

Changes in these general instructions will undoubtedly be made from time to time as better methods are developed. The members of the field and office forces of the Survey engaged on the precise traverse and its computations are invited to offer suggestions which may make it possible to do the work more expeditiously without decreasing the accuracy or increasing the cost.

GENERAL STATEMENT.

Precise traverse will, in general, be done in those sections of the country where the topographic conditions make it impracticable to carry on primary triangulation. The work will supplement the primary triangulation in furnishing the fundamental control for the surveys and maps made by federal, State, or other organizations and by private individuals. The conditions which make it more desirable to carry on precise traverse than primary triangulation are flatness of the land and presence of timber. Under these conditions it is necessary to have comparatively short lines in the primary triangulation, and to erect high scaffold signals at the stations in order to make them intervisible.

These instructions are designed for the highest class of traverse, equal in accuracy to primary triangulation, and for secondary traverse comparable in accuracy with secondary triangulation. Should it be necessary to carry on tertiary traverse for the control in local areas, special instructions will be furnished to officers in charge of the field work.

LOCATION OF TRAVERSE STATIONS.

1. In general the traverse will be run along a railroad track. The stations should usually be at the intersection of two contiguous tangents of the railroad. Occasionally when the tangent is particularly long and the profile of the road between its ends such that it would be difficult to get a line clear between the ends of the tangent, one or more intermediate stations should be placed at the side of the road. The profile of the road along the tangent will be the deciding factor in the location of the intermediate stations. If the ground is practically level along such a tangent, the stations may be placed almost anywhere, and should be located near a crossroad, if convenient.

2. In general the stations along any tangent should not be more than 4 or 5 miles apart, as delays caused by observing longer lines will more than offset the time gained by having fewer observations. It is also true that stations should be placed fairly close together, so as to be of the maximum benefit for public and private surveys.

3. A traverse station should be placed near each railroad crossing or point where a branch line makes off from the line followed by the traverse. Also a traverse station should be located at or very near each town along the route of the traverse, and when at all practicable a second traverse station should be located within 2 miles of the town in order to enable local engineers and surveyors to obtain an azimuth with little difficulty.

4. When curves are numerous for any given distance and the tangents very short, it will be well to lay out comparatively long lines extending over several curves in order that the azimuth may be carried forward with greater strength than if it had to be carried through a number of short lines. The distance between the ends of such a long line can be carried by measurement and angles along the track. This latter work would be considered in the nature of a subsidiary scheme of angles. Care must be taken that each end of such a long line is carefully tied into the scheme running along the railroad between its ends.

MEASUREMENT OF DISTANCES.

5. The lengths in the traverse will depend on measurements made with 50-meter invar base tapes, standardized at the Bureau of Standards before and after use in the field.

6. The length should depend upon one measurement in one direction only, unless a blunder has been made. There should be three primary tapes in the party, two used in measurement and one used as a standard. About one-half of the measurement of any considerable portion of the traverse should be made with each of the working tapes. A comparison should be made of the three tapes at intervals along the traverse in order to detect any changes that might occur in the length of one or both of the working tapes. No tape should be used for more than 15 kilometers of measurement without being recompared. The comparison of the three base tapes can best be made on the stakes used in the traverse measurement between a point of tangency and a traverse station. A distance of at least 100 meters should be used in making the comparison. Metal strips should be used on the top of the stakes employed for the comparison to prevent parallax in marking. The comparison of the tapes with a record of temperatures, etc., should be entered in the traverse record.

7. A tape should be sent to the office for restandardization if it differs by more than 1 part in 75 000 from the standard tape.

8. As soon as a new tape has been received from the office a comparison of this tape should be made with the standard tape and the other working tape or tapes. No actual field work should be done with the new tape until such a comparison has been made.

9. Do not straighten out kinks in the tape. If such exist and the tape, in consequence, can not be used for measurement, send the tape to the office with a letter explaining in detail this condition, giving date on which the injury or injuries occurred.

10. The base tapes used in the field should have a tension applied of 15 kilograms, and this same tension will be used during the standardization at the Bureau of Standards.

11. Two thermometers should be attached to the tape, one at each end, during measurement, and they should be read and recorded at each tape length. Special centigrade thermometers, for use during traverse or base measurement, will be furnished by the office on application. In attaching the thermometers to the tape suitable cases should be used which will insure good contact with the tape and prevent the breaking of the thermometer. They should be attached to the tape beyond the end graduations in order to guard against any tendency to kink the working part of the tape. The cases can be fastened to the tape by means of adhesive tape, and this will make it possible to detach them easily when the tape is wound on the reel.

12. A second measurement, with a primary tape, will be made over any section of the line of traverse which is to be used as a base line from which to start an arc of primary triangulation.

13. When measuring along a railroad, the distances along the tangents will be measured with the 50-meter tape, supported throughout its length on top of a rail of the track. The distances from the points of tangency to the traverse stations at the intersection of tangents, should be measured over stakes especially set to support the tape.

14. In measuring up to or away from a station the record should indicate clearly whether the tape was held on the station mark itself or on the bench or table built over the station mark. In this connection do not use the word "tablet" for the station mark, as it is easily confused with the word "table."

15. In measuring the offset distance between the point on the rail and the station itself, for stations along tangents, the record should show whether the measurement was made horizontally or on an incline, and in the latter case the difference in elevation must be given.

16. The record should also indicate clearly whether the traverse was measured to a rail station, to the rail opposite a station, or to the station itself. A rail station proper is one which is actually on the rail itself and is occupied with a theodolite for observations of the same degree of accuracy as for the regular scheme. A rail station is usually put in to aid in determining some point at some distance from the track. It is very rare that there will be another traverse station within one or two hundred meters of the rail station.

17. While measuring along the top of a rail, the position of the forward end of the tape can be transferred to the rail with an ordinary cheap glass cutter. In measuring over stakes, the forward end of the

tape will be marked directly on the top of the stake by means of a knife cut or a mark with a glass cutter. If the top of the stake is badly battered, an ordinary pin may be driven in to mark the end of the tape.

18. The rear contact man must use the same end of the small scratch on the rail as was used by the forward contact man. This will be brought about by the two contact men always standing on the same side of the tape.

19. Great care must be exercised in counting and recording the number of tape lengths in a section. At least one other man in the party besides the recorder should count the tape lengths entirely independently. It is suggested that a system of counting tape lengths similar to the one used in ordinary surveying be tried out by the taping party. Small tin or aluminum rings or harness rings two or three inches in diameter could be used for the purpose. For each tape length one of these rings could be left beside the rail close to the mark on the rail by the forward contact man and later picked up by the rear contact man. Twenty one rings could be used and 20 of them passed to the forward contact man at the end of each kilometer. A piece of colored rag tied to the ring will enable the rear contact man to find it readily. The rings can be carried by means of a spring attached to the handle of each of the tape stretchers.

20. To avoid gross errors, all fractions of a tape length less than about 49.9 meters, which enter into a section, should be measured as set-ups. The set-ups will be measured with a standardized pocket steel tape or metal scale, except as provided for in paragraph 21.

21. When a fraction of a tape length is greater than 25 meters, it should be measured as two set-ups; the first one as half a tape length and the balance as a set-up to be measured with the pocket steel tape. A half tape length can easily be measured by placing a mark with a pencil or otherwise near the center of the base tape. Then the distance from the stake ending the last full tape length to a point on a stake set approximately 25 meters can be measured twice, once with each half of the tape, and the error in marking the middle of the tape can thus be eliminated.

22. In setting stakes on the prolongation of tangents it will be of advantage to begin at the station and work toward the rail in either direction, for this will bring the minimum number of set-ups on the stakes, and all half tape lengths on the stakes will be eliminated. When measuring by this method, all necessary large set-ups will occur on the rail, where they are easily measured.

23. A railroad curve often occurs in a deep cut, which makes it necessary to put the traverse station at the top of a high bank and renders the staking and taping difficult. If a saving of time can be made, it is permissible to compute the distance from the stake, beyond which the taping would be difficult, to the station by means of a triangle. A small base should be measured from this stake to another stake at some convenient point along the curve which will give a triangle with a good angle of intersection at the station. The angles should be measured with such accuracy as to insure against an error as great as one-half centimeter in the computed distance. The same method may be used in going ahead from the station.

24. During the measurement with the base tape, indicate in the record the distance from the initial point of the section to crossroads, railroad stations, water towers, section houses, semaphores, bridges, culverts, mileposts, banks of rivers, State and county lines, decided changes of grade and possibly some other objects, in order that the traverse may be properly connected with the alignment of the railroad, and thus make it possible to utilize the railroad surveys in making maps of the country through which the traverse runs. These measurements will also be utilized in making a determination of the geographic positions of some of the objects to which distances are measured. The record must show whether the taping is along the left-hand or right-hand rail. Instructions in regard to the angles to be measured to objects along the road are given on another page.

25. The designations of the points of tangency and their distances from the initial station of the section should be carefully recorded; as, for example, P. T. 42=24+4. (24+4 means 4 meters beyond the end of the 24th tape length). In case the precise leveling precedes the taping, the designation of all permanent and temporary bench marks along the track, and their distances from the initial station, should also be recorded, as for example, 6+20=T. B. M. 115.

26. No measurement should be made with the primary tape when the rail is wet, and when it is damp measurements should be made with caution. It is the experience of those engaged on measurement along railroad tracks that the tape tends to stick to the rail when the latter is wet, and therefore errors will result.

CHECK MEASUREMENT.

27. A single check measurement will be made of each section of the traverse with a 300-foot tape. The best means of recording the number of full tape lengths is to read and record the temperature each time. Only one thermometer need be used. Counters may be used

as a check on the number of tape lengths. When measuring from the P. T. point to the station the tape may be supported on the stakes that were used for the invar tape, but no other regard should be given to these stakes. Plumb lines should be used at the ends of the tape, the same as in ordinary chaining, and the point marked on the ground with an iron pin.

28. The 300-foot tape may be supported along the top of the rail or on the ties close to the rail while measuring between tangent points. The position of the forward end of the tape may be indicated on the top of the rail by a pencil mark. The location of the pencil mark may be indicated by a cross made with chalk or keel on the rail or a tie. The distances between the points of tangency and the traverse stations should be measured as in ordinary chaining without reference to the original stakes.

29. A moderate pull only should be used with the 300-foot tape. It is believed that five kilograms is sufficient. The object of having a light pull is to make it possible to have the measurement made with a very small party. A heavy pull would require the use of stretchers at the forward and rear ends of the tape. The lengths of the tapes under the standard pull and temperature must be known.

30. During the check measurement, distances should be indicated in the record from the traverse station at the beginning of the section to the country road and railroad crossings, to bridges, water tanks, mileposts, and other objects, as given in paragraph 24, in order that a check may be made on the determination of the distance of these objects from the traverse station. Designations of all points of tangency and all bench marks along the track and their distances from the initial station should be carefully recorded; as, for example, 1+235= P. T. 42, and 11+135=T. B. M. 115.

31. Measurements with the 300-foot tape may be made under any conditions of the weather.

32. If the temperature is not recorded for each tape length, as suggested in paragraph 27, the approximate temperature of the tape should be entered in the record at least once for each section.

33. If the measurement with the 300-foot tape differs by more than a few decimeters in any section from the distance given by the measurements with the 50-meter base tape, a second measurement with the 300-foot tape will be made. If this second measurement agrees closely with the first one made with the 300-foot tape, then a second measurement will be made with the 50-meter tape.

ANGLE MEASUREMENTS.

34. In general, the highest type of instrument will be used in measuring the angles of the main line of traverse stations. When a direction instrument is used which is read by micrometer microscopes, the angles will be measured in eight positions of the instrument. The initial settings for these positions are as follows:

Position No.	Reading.		
	°	′	″
1	0	00	40
2	30	01	50
3	60	03	10
4	90	04	20
5	125	00	40
6	155	01	50
7	185	03	10
8	215	04	20

35. When the measurement of an angle in the main line of traverse stations is made with a 7-inch repeating theodolite, a sufficient number of observations should be made to obtain the same degree of accuracy as can be obtained by measuring the angle in eight positions with the direction theodolite. It is probable that about three sets, each consisting of six repetitions of the angle with the telescope direct and six repetitions of the explement with the telescope in the reversed position, will be needed to secure the degree of accuracy desired.

36. A position for a direction instrument consists of a pointing on each object in the horizon, in both direct and reverse positions of the telescope, for one initial setting of the horizontal circle.

37. Observations for angle measurements at the principal stations of the traverse should be made only when the conditions are favorable. To an inexperienced observer this can be determined only by experiment. It will be found that a steady signal does not always mean that observing conditions are perfect, for it is possible that there may be lateral refraction under the conditions that obtain when the signal appears steady that might be absent when the signal is tremulous or jumpy. Excellent observations can be obtained on a signal that is moderately unsteady when a number of repetitions of the angle or direction is made. The amount of unsteadiness that will still permit good observations to be obtained can be determined approximately by the observer. He can observe some one direction under various

weather conditions and note the agreement in the angle or direction obtained under each condition.

38. The 7-inch repeating theodolite should be used in measuring all angles at subsidiary traverse stations which are not used for carrying the main azimuth ahead. One set of six repetitions of the angle with the telescope in the direct position, followed by a set of six repetitions of the explement of the angle with the telescope in the reversed position, is sufficient.

39. The instrument and the object sighted upon should be accurately centered, or, if they are eccentric to the traverse stations, the eccentric distance and direction should be carefully measured and entered in the records. The direction from the eccentric instrument station to the true station, or from the station to the eccentric object, should be entered in the list of directions and should be referred to the same initial station as the other directions from that station. Confusion is caused by recording the eccentric as "2.5 centimeters right."

40. One of the greatest sources of error in triangulation or other angle measurements is what is known as phase. This is caused by uneven illumination of the object sighted on, thus causing the observer to point his cross wires to the right or left of the center of the object. When the sun is shining, a round or square pole will always have phase unless the sun is exactly in line with the instrument and the pole, except that a square pole will not have phase if one face of the pole is at right angles to the line to the observer. Phase may be eliminated almost entirely by having a thin strip of board centered directly over the station mark. It is probable that the signal on which the instrument will be mounted can be made in such a way that a pole 4 inches square can be set into the top of the tripod. This pole can be constructed of two pieces of 2 by 4 inch material, and between the two pieces at the upper end can be placed the thin piece of board on which the observations are to be made.

41. At each traverse station observe directions to such objects along the track as mileposts, water towers, semaphores, railroad stations, section houses, and any other objects that may be visible. (See paragraph 24.) With the angle or direction to these objects and the distances measured during the determination of the distances along each section, the geographic positions of a number of objects which may be of great geographic value may be determined. It is particularly important that angles or directions should be observed to objects distant from the railroad which may be determined by observations from several traverse stations. Each object of a more or less permanent nature whose geo-

graphic position can be computed from the angles and distance measurement made by the traverse increases the engineering and geographic value of the work.

AZIMUTH STATIONS.

42. Owing to the fact that errors in angle observations on a traverse tend to accumulate, it is necessary to observe frequent astronomic azimuths. The observations should be made on Polaris.

43. In general, an azimuth station of primary accuracy will be established at intervals of about 30 or 35 traverse stations. Observations for azimuth should be made only at main line traverse stations (see par. 46). The locations of the Laplace azimuth stations will be given in the special instructions for each particular piece of work.

44. The azimuths may be observed by the method of repetitions with a 7-inch theodolite. For any instrument double the number of observations should be made for azimuth as for a horizontal angle at a main traverse station. The probable error of a primary azimuth should not exceed $\pm 0.''50$ and for a Laplace station should not exceed $\pm 0.''30$.

45. At intervals of about 10 traverse stations secondary azimuth stations should be established between the primary azimuth stations. The accuracy of the secondary azimuths should be that represented by a probable error of about $\pm 5''$.

46. In order that the geodetic azimuth may be carried along the traverse with a minimum error, it will be well to have stations on or off the road or railroad along which the traverse is measured which are intervisible for much longer distances than between the regular traverse stations. The azimuth can be carried through these extra stations; but whenever used, the extra stations should be connected in azimuth and distance with the regular traverse stations and should always be used instead of one of the regular stations for the azimuth observations. The angles measured at regular stations along any portion of the line where there are extra stations should be adjusted to the angles measured at the extra stations. The extra stations, rather than the regular stations along the same piece of traverse, will be used in determining where an azimuth station will be located.

MARKING STATIONS.

47. The standard triangulation and reference marks should be used in marking the traverse stations. (See p. 42 of Special Publication No. 26.) They should be set into heavy blocks of concrete or stone to insure permanency.

48. On the standard station and reference marks should be stamped the name of the traverse station, and, if the station mark is used as a bench mark, the letter and number designating the bench mark should also be stamped on the tablet.

49. All traverse stations should be marked when each two contiguous stations are a mile or more apart. When the track along which the traverse is made has numerons curves and short tangents, some of the traverse stations need not be marked in a permanent manner. In general, there should be a permanently marked station at least every 3 miles along the traverse, except, of course, when a section of the traverse along a tangent is more than 3 miles in length. When a station is marked in a permanent manner, the next station back of it or ahead of it must be marked also in a permanent manner, in order that anyone using the traverse may be able to obtain an azimuth. The station should be marked with an underground as well as a surface mark. The underground mark may be a bottle or some other object, preferably set in a small block of concrete. It is frequently the case that the underground mark will be left intact when the surface mark is destroyed.

50. At each station marked in a permanent manner there should be placed a reference mark. This reference mark should consist of concrete or rock, into which is set a standard inscribed reference mark. It should be so accurately connected in distance and azimuth with the station mark that it may be used as the station mark if the latter should be destroyed. It should be placed in such a position that it will not be liable to be destroyed by the same agency that might destroy the station mark itself.

51. Traverse stations which are not marked in a permanent manner should be marked temporarily with a suitable wooden or other kind of stake in order that the station may be available for several years after its establishment. Wood which resists decay, such as cedar or Georgia pine, should be used if it can be obtained easily.

DESCRIPTIONS OF STATIONS.

52. All stations of the traverse, whether marked permanently or in a temporary manner, should be described in such a way that they may be recovered easily. The descriptions should include the distance from the nearest milepost and railroad station and also the offset distance from the nearest rail of the railroad track. The station mark and the reference mark should be described by notes, as given on pages 42 and 43 of Special Publication No. 26. If a new type of station mark is used which is not covered by one of those notes, a new note should

be added and given a number. The Chief of the Division of Geodesy should be notified that a new note is being used, and the wording of the note and its number should be furnished him as soon as practicable after its adoption.

53. It is often desirable in writing descriptions of stations to give approximate distances to various near-by objects which are not important or definite enough to justify an accurate measurement to them. Whenever possible, these distances should be paced, as gross errors are often made in estimating, and erroneous distances cause confusion when the station is recovered.

54. The descriptions should be made on the cards furnished by the office for the descriptions of triangulation stations. The writer of the descriptions should have in mind that the descriptions will be published in the near future, and they should be in such a condition, therefore, that the minimum amount of editing will be necessary in preparing the manuscript for the printer. Any facts essential to the recovery of the station should be given, but those features of only a temporary nature should not be mentioned in the description.

INCLINATION CORRECTIONS.

55. In general, a line of precise levels will be run along the line of traverse at the same time that the traverse is measured. This leveling will be connected with such points of the traverse as will make it possible to compute the inclination corrections of the measured distances. Precise leveling will be carried on in accordance with the general instructions for precise leveling contained in Special Publication No. 22 of the United States Coast and Geodetic Survey, or in later leveling publications, except as may be modified by the instructions for carrying on primary traverse.

56. There will be determined by the precise leveling party the elevations of any points of decided change in grade along a tangent. There will also be determined the elevation of the rail opposite all mileposts, water towers, section houses, railroad stations, and over all bridges and culverts. There will also be determined the elevation of all points of tangency which have been indicated by the traverse measuring party or which may be indicated by the leveling party, if the leveling precedes the measurement. Points of tangency should be marked on the rail or ties of the track by a cross, or otherwise. A designation or number should be given to the point of tangency—as, for example, P. T. 42—in order that there may be no doubt as to the identification of the records of the measuring and leveling parties for any one section.

57. The traverse stations which have been marked in a permanent manner will be used as the bench marks on the line of levels. In addition, the leveling party will establish bench marks in each of the towns and cities through which the line passes, in order that the city surveyors and engineers may have sufficient bench marks to control the elevations of their various public works.

58. None of the reference marks should be used as bench marks in the line of levels, as it has been found in the Office, when making the final computations, that the records are apt to be confusing when two bench marks are so close together as a traverse station and its reference mark. The precise leveling done in connection with the primary traverse along a railroad should follow the setting of the station marks of the traverse stations. This will make it possible to use the traverse stations as bench marks and will avoid the necessity for setting other bench marks. If the leveling party should be held back at all on this account, the members of the leveling party can assist the traverse party in any way that is possible and work on their own records until the marking of the traverse stations has been carried ahead. The traverse party should do everything that is possible to keep the stations marked ahead of the leveling, in order that the leveling party may not be delayed.

59. When carrying the line of levels from the railroad into a town for the purpose of connecting with the bench marks established on masonry, brick, concrete, or other structures, the place where the leveling left the track should be indicated in the records. When the leveling has returned to the track, the rod should be held as nearly as possible on the same turning point that was last used when the line of levels left the track and a proper note should be made in the record. If this is done, it will be possible to get a continuous profile of the track over which the traverse is run, for use in computing the inclination corrections.

60. Two rod readings should be taken on the rail opposite each traverse station or bench mark which has been established on the side of a tangent. One of these readings should be made from the instrument station just before getting to the point opposite the traverse station or bench mark, and the second rod reading should be made from the first instrument station after passing the traverse station or bench mark. This will make it possible for the computer to get a continuons profile between traverse stations and also obtain a rough check on the measured distances. It should be borne in mind that distances as well as elevations are computed from the precise levels. If the

leveling is done according to these instructions, gross errors in the taping will be discovered in computing the distances for the grade corrections.

61. At all times when an extra rod reading is taken it should be indicated in the record by the letters F or B according to whether the reading was taken in front of the instrument or back of it.

62. There should be noted in the record the points in the line of levels at which decided changes of grade occur.

63. Care should be taken to show clearly in the record when readings are made opposite a railroad station if there is a traverse station near-by having the same name.

64. In carrying on precise leveling one rod may be kept ahead for a whole section, and then for the next section the other rod can be kept ahead. By alternating the rods for successive sections no appreciable error will enter into the leveling, and in many cases the work will be expedited. This method should be used only if better progress can be made than by the usual method of having the same rod at a rod station for both the fore sight and the back sight.

65. Except in special cases the inclination corrections for the distance from the points of tangency to the traverse stations should be determined by levels run especially for the purpose and separate from the precise leveling. The leveling over the stakes need have only such accuracy as is necessary to obtain the grade correction for any one tape length with an error not in excess of one millimeter or one part in 50 000. There should be both a forward and backward running with different instrument stations.

66. In recording the levels over the stakes care should be used to give the stakes the same designation as in the traverse record.

67. A leveling rod graduated to meters should be used for the Y levels in order to avoid the necessity for the conversions from feet to meters in joining the Y levels with the precise levels. It is recommended that a Y level equipped with stadia wires be used on this work in order to give an additional check on the distances measured over the stakes. The offset distance of each instrument station not in the line of stakes should be paced and noted in the record in order that proper allowance can be made in computing the check distances over the stakes.

RECORDS AND COMPUTATIONS.

68. There are given below samples of records, abstracts, computations, and results in connection with primary traverse. These samples should be followed unless authority has been given by the Superintendent to deviate from them.

69. The following samples of records and computations, with the exception of the computation of loop closure, are all for the same section of the traverse, namely, from station North to station Douglas of the Savannah-Norfolk traverse line. This makes it possible for

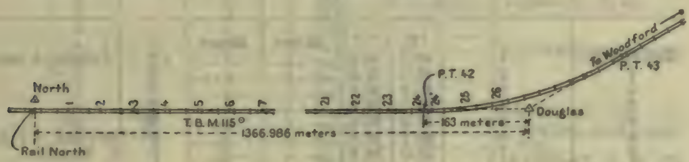

FIG. 1.—Section of traverse line.

anyone desiring to do so to follow through the various steps of the computation and see how each value is obtained. The section selected is a typical one with one station at the intersection of two tangents and the other an offset station on a long tangent.

70. All angles of the traverse are measured and recorded as in triangulation, instructions for which have already been published in Special Publications Nos. 19 and 26. No samples of the angle measurements are included in this publication.

71. Traverse measurement.—

From station North to station Douglas, forward measurement.

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form 590.

[Date, 5-11-18; time, 10.30 a. m.; tape No. 552; bal. No. 266.]

Section.		Temp.		Set-up.	Setback.	Tape support.	Remarks.
From—	To—	Forward.	Rear.				
		°*C.*	°*C.*	*Meters.*	*Meters.*		
Rail North.	1	43.5	44.0	....	....	[a] T	Left-hand rail.
1	2	41.3	41.0	....	....	T	
2	3	40.2	39.8	....	....	T	
3	4	39.1	38.9	....	....	T	
4	5	37.0	38.6	....	....	T	
5	6	36.1	38.5	....	....	T	{6+20 m.=T.B. M. 115.
6	7	35.0	34.9	....	....	T	
7	8	36.8	36.4	....	....	T	
8	9	36.6	36.1	....	....	T	
9	10	36.4	35.9	....	....	T	{11+7 m.=W.R. X. (wagon-road crossing).
10	11	36.4	34.9	....	....	T	
11	12	37.3	36.9	....	....	T	
12	13	38.0	37.1	....	....	T	
13	14	38.6	37.3	....	....	T	
14	15	38.4	38.4	....	....	T	
15	16	38.4	39.6	....	....	T	
16	17	39.3	39.7	....	....	T	
17	18	39.2	39.8	....	....	T	
18	19	38.5	39.9	....	....	T	
19	20	39.2	41.0	....	....	T	
20	21	43.5	44.3	....	....	T	
21	22	41.4	44.5	....	....	T	
22	23	40.0	43.9	....	....	T	
23	24	40.0	42.9	....	....	T	{S. U.=55′ 11$\frac{5}{8}$″ 24+4 m.=P. T. 42.
24	24′	......	......	17.0565	....	T	
24′	25	37.4	34.8	....	0.0445	3	
25	26	36.7	35.1	....	....	3	Chief of traverse measuring subparty: J. Smook.
26	Table Douglas.	34.8	32.9	0.0110	....	3	
Means and totals.......		......	......	17.0675	0.0445		

[a] A "T" in this column means that the tape is supported throughout, a "3" or a "5" means the number of equally spaced supports.

72. Check measurement.—

From station Douglas to station North, backward measurement.

[Date, 5-13-18; time, 9 a. m.; tape No. 251 (300-foot).]

Section. From—	Section. To—	Temperature.	Set-up.	Set-back.	Remarks.
		°C.	Feet.	Feet.	
Table Douglas.	1	37.1	....	....	
1	2	36.5	....	....	1+235′=P. T. 42.
2	3	35.4	....	....	
3	4	35.0	....	....	
4	5	34.8	....	....	4+4′=kilometer mark.
5	6	34.6	....	....	
6	7	34.3	....	....	
7	8	34.1	....	....	
8	9	34.2	....	....	8+257′=W. R. X. (wagon road crossing).
9	10	34.6	....	....	
10	11	34.9	....	....	
11	12	35.2	....	....	11+135′=T. B. M. 115.
12	13	35.5	....	....	
13	14	36.1	....	....	
14	Rail north.	36.4	284.8	....	

Total length=4484.8 feet=1366.97 meters; original measurement=1367.02 meters.

The check measurement may be recorded in the regular traverse book, Form 590, by making a few changes in the headings.

73. Y levels over stakes.—

Station Douglas.

[Date, 5-14-18; time, 11.30 a. m.; Y level, 93.]

Rod station.[a]	Forward running. Back sight.	Forward running. Fore sight.	Forward running. Difference of elevation.	Rod station.	Backward running. Back sight.	Backward running. Fore sight.	Backward running. Difference of elevation.	Mean difference of elevation.
	Feet.	Feet.	Feet.		Feet.	Feet.	Feet.	Feet.
P. T. 42	1.04	....	....	P. T. 43	6.75	....	....	....
24′	....	1.38	−0.34	3	....	6.89	−0.14	+ 0.16
25	....	1.20	+0.18	2	....	5.80	+1.09	− 1.10
26	....	0.83	+0.37	1	....	6.15	−0.35	+ 0.34
Table at Douglas.	....	2.84	−2.01	Mark at Douglas.	....	3.54	+2.61	− 2.60
Mark at Douglas.	....	3.93	−1.09	Table at Douglas.	....	2.45	+1.09	− 1.09
1	....	6.52	−2.59	26	....	0.43	+2.02	− 2.02
2	....	6.18	+0.34	25	....	0.80	−0.37	+ 0.37
3	....	7.29	−1.11	24′	....	0.96	−0.16	+ 0.17
P. T. 43	....	7.12	+0.17	P. T. 42	....	0.60	+0.36	− 0.35

[a] Y level readings should be recorded in the same order as the points sighted on actually occur along the traverse line, in the direction of progress.

74. For convenience in printing, the backward and forward runnings of the Y levels over the stakes are given together in the preceding table. In the field the two runnings should be recorded on different pages, separated by a page or two in order to avoid duplication of errors by the recorder. A third running should be made if the first two fail to check.

75. Precise levels.—

T. B. M. 115 to B. M. A_2 (forward).

	Backsights. Foresights.
	223500000
	233600000
	243800000
	720
	820
	921
	1479*n*[a]
Rail at T. B. M. 115 (B)	1579*n*
	1680*n*
	281
	428
	575
	258200000
	273100000
	288000000
	256300000
	271100000
	286000000
	504
	651
	799
	814
	962
	1110
	249300000
	264200000
	279100000
	120400000
	133700000
	147000000
	2180
	2328
	2476
	1818*n*
P. T. 42 (F)	1890*n*
	1963*n*

	Backsights. Foresights.
	2003
	2136
	2269
	70900000
	84300000
	97700000
	1538*n*
Rail at △ Douglas (F)	1561*n*
	1584*n*
	128700000
	140500000
	152300000
	1100
	1219
	1338
	1539*n*
P. T. 43 (F)	1549*n*
	1559*n*
	954
	1025
	1097
	225400000
	232700000
	240000000
	1481*n*
Rail at B. M. A_2 (F)	1552*n*
	1623*n*
	4899828710

Diff. of sums = +20288
Diff. of sums divided by 3 =
Diff. of elev. = +6762.7

[a] All numbers in this table marked with an "*n*" are not included in the total, as they were put in the adding machine with the "non-add" key depressed.

SAMPLE COMPUTATIONS AND TABLES.

76. The various steps in making a traverse computation are as follows:

(*a*) Checking list of directions from the original angle records.

(*b*) Computation of grade corrections and mean elevations of sections.

(*c*) Computation of lengths on Form 589, including temperature, tape, and sea-level corrections.

(*d*) Projection computation or computation of lengths between the true stations when the tape measures were made to a point on the rail opposite the station at either or both ends.

(*e*) Closure of loops when the azimuth is carried through long lines extending past several stations. (See par. 46.)

(*f*) Computation of geographic positions. As there is no check on this computation, it must be made in duplicate.

(*g*) Final least square adjustment to make the traverse lines consistent with each other and with the triangulation with which they connect.

77. Various tables which are useful in making the computations are given on the following pages just after the computation in each case for which they are needed. The first one of these tables giving the inclination correction for different lengths of section and differences of elevation will be found on page 25. This is used for computing the inclination corrections when these corrections depend upon the precise levels. Following the computation of lengths on page 33 are several tables of tape corrections for tape No. 552 for various methods of support. These tables can be used only for this one standardization of this particular tape. Each tape and each new standardization requires new tables. Whenever a tape is used for any considerable length of time it will be found to save much work in the long run to construct tables similar to the ones published here.

78. Computation of inclination correction.—

From station North to station Douglas.

Bench mark.	Difference of elevation.	Distance.	Inclination correction.[a]	Elevation.	Remarks.
	Meters.	*Meters.*	*Millimeters.*	*Meters.*	
Rail North—	−0.01	16	0.0	103.05 [b]	Precise level record, Vol. 15 (*see* page 22).
	−0.59	199	0.9	....	
—Rail 115	−0.15	102	0.1	102.29 [b]	
Rail 115—	+0.76	134	2.2	....	
	+2.30	197	13.4	....	
	+2.06	197	10.8	....	
	+1.68	198	7.1	....	
—P. T. 42	−0.55	137	1.1	....	
P. T. 42—24′	*−0.11*	*13*	*0.5*	....	Traverse record, Vol. 6 (*see* page 20), and wye-level record, Vol. 1 (*see* page 21).
24′—25	*+0.05*	*50*	*0.0*	....	
25—26	*+0.11*	*50*	*0.2*	....	
26—Table / Douglas	*−0.62*	*50*	*3.8*	107.98	
Total		1343[c]	40.1	....	
Mean elevation				105.3	

[a] The corrections in this column were obtained from the table on page 25, except for the last part of the section, shown in italics, for which the corrections were obtained from the table on page 28.

[b] The mean of these two elevations was used in computing the mean elevation for the whole section.

[c] Due to the use of a convenient but slightly inaccurate value of the stadia constant for the precise level, this distance fails to check the measured distance. The percentage of error is quite small, and by comparing several sections its value can be obtained quite accurately and allowance made for it. If the precise leveling has been done according to the instructions in this publication, this check on the distance should locate any blunder of a tape length in the tape measurement.

79. With regard to the preceding computation it should be noted that the table on page 25 differs from the one on page 28 in this respect, that in the former the known measured distance, l, is the horizontal distance or leg of the right triangle, while in the latter it is the inclined distance or hypotenuse of the right triangle. This distinction should be kept in mind in computing any values which fall outside the limits of the tables.

80. In computing inclination corrections outside the limits of the table on page 25 for the precise-leveling work it will be found that the first term only of the series formula at the top of the table, namely, $\frac{1}{2}\frac{h^2}{l}$, will give sufficient accuracy. The same formula may also be used for the Y-level work when the lengths are other than the 25 or 50 meters for which the table on page 28 is computed and when the

grades are under 5 per cent. Of course h must be expressed in meters instead of feet. Other values outside the limits of the tables can be obtained readily by actually computing the right triangle. Barlow's tables of squares will be found useful in this connection.

81. Inclination correction.—

[Correction $= l - \sqrt{l^2+h^2} = -\frac{1}{2}\frac{h^2}{l} + \frac{1}{8}\frac{h^4}{l^3} - \ldots.$ (always negative).]

Length of section in meters.	Difference of elevation in meters.										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
10.....	0.0	0.5	2.0	....	....	....	....	....	....	....	....
20.....	....	0.2	1.0	2.2	4.0	....	....	....	....	....	....
30.....	....	0.2	0.7	1.5	2.7	4.2	6.0	8.2	10.7	....	....
40.....	....	0.1	0.5	1.1	2.0	3.1	4.5	6.1	8.0	10.1	12.5
50.....	....	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10.0
60.....	....	0.1	0.3	0.8	1.3	2.1	3.0	4.1	5.3	6.8	8.3
70.....	....	0.1	0.3	0.6	1.1	1.8	2.6	3.5	4.6	5.8	7.1
80.....	....	0.1	0.2	0.6	1.0	1.6	2.2	3.1	4.0	5.1	6.2
90.....	....	0.1	0.2	0.5	0.9	1.4	2.0	2.7	3.6	4.5	5.6
100.....	....	0.0	0.2	0.4	0.8	1.2	1.8	2.4	3.2	4.0	5.0
110.....	....	....	0.2	0.4	0.7	1.1	1.6	2.2	2.9	3.7	4.5
120.....	....	....	0.2	0.4	0.7	1.0	1.5	2.0	2.7	3.4	4.2
130.....	....	....	0.2	0.3	0.6	1.0	1.4	1.9	2.5	3.1	3.8
140.....	....	....	0.1	0.3	0.6	0.9	1.3	1.7	2.3	2.9	3.6
150.....	....	....	0.1	0.3	0.5	0.8	1.2	1.6	2.1	2.7	3.3
160.....	....	....	0.1	0.3	0.5	0.8	1.1	1.5	2.0	2.5	3.1
170.....	....	....	0.1	0.3	0.5	0.7	1.1	1.4	1.9	2.4	2.9
180.....	....	....	0.1	0.2	0.4	0.7	1.0	1.4	1.8	2.2	2.8
190.....	....	....	0.1	0.2	0.4	0.7	0.9	1.3	1.7	2.1	2.6
200.....	....	....	0.1	0.2	0.4	0.6	0.9	1.2	1.6	2.0	2.5
210.....	....	....	0.1	0.2	0.4	0.6	0.9	1.2	1.5	1.9	2.4
220.....	....	....	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.8	2.3
230.....	....	....	0.1	0.2	0.3	0.5	0.8	1.1	1.4	1.8	2.2
240.....	....	....	0.1	0.2	0.3	0.5	0.7	1.0	1.3	1.7	2.1
250.....	....	....	0.1	0.2	0.3	0.5	0.7	1.0	1.3	1.6	2.0
260.....	....	....	0.1	0.2	0.3	0.5	0.7	0.9	1.2	1.6	1.9
270.....	....	....	0.1	0.2	0.3	0.5	0.7	0.9	1.2	1.5	1.9
280.....	....	....	0.1	0.2	0.3	0.4	0.6	0.9	1.1	1.4	1.8
290.....	....	....	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.4	1.7
300.....	....	....	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.3	1.7

Inclination correction—Continued.

Length of section in meters.	Difference of elevation in meters.									
	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
40.....	15.1	18.0	....	....	....	....	....	....	....	....
50.....	12.1	14.4	16.9	19.6	22.5	25.6	....	....	....	....
60.....	10.1	12.0	14.1	16.3	18.8	21.3	24.1	27.0	30.1	33.3
70.....	8.6	10.3	12.1	14.0	16.1	18.3	20.6	23.1	25.8	28.6
80.....	7.6	9.0	10.6	12.2	14.1	16.0	18.1	20.2	22.6	25.0
90.....	6.7	8.0	9.4	10.9	12.5	14.2	16.1	18.0	20.1	22.2
100.....	6.0	7.2	8.4	9.8	11.2	12.8	14.4	16.2	18.0	20.0
110.....	5.5	6.5	7.7	8.9	10.2	11.6	13.1	14.7	16.4	18.2
120.....	5.0	6.0	7.0	8.2	9.4	10.7	12.0	13.5	15.0	16.7
130.....	4.7	5.5	6.5	7.5	8.7	9.8	11.1	12.5	13.9	15.4
140.....	4.3	5.1	6.0	7.0	8.0	9.1	10.3	11.6	12.9	14.3
150.....	4.0	4.8	5.6	6.5	7.5	8.5	9.6	10.8	12.0	13.3
160.....	3.8	4.5	5.3	6.1	7.0	8.0	9.0	10.1	11.3	12.5
170.....	3.6	4.2	5.0	5.8	6.6	7.5	8.5	9.5	10.6	11.8
180.....	3.4	4.0	4.7	5.5	6.3	7.1	8.0	9.0	10.0	11.1
190.....	3.2	3.8	4.4	5.2	5.9	6.7	7.6	8.5	9.5	10.5
200.....	3.0	3.6	4.2	4.9	5.6	6.4	7.2	8.1	9.0	10.0
210.....	2.9	3.4	4.0	4.7	5.4	6.1	6.9	7.7	8.6	9.5
220.....	2.7	3.3	3.8	4.5	5.1	5.8	6.6	7.4	8.2	9.1
230.....	2.6	3.1	3.7	4.3	4.9	5.6	6.3	7.0	7.8	8.7
240.....	2.5	3.0	3.5	4.1	4.7	5.3	6.0	6.7	7.5	8.3
250.....	2.4	2.9	3.4	3.9	4.5	5.1	5.8	6.5	7.2	8.0
260.....	2.3	2.8	3.2	3.8	4.3	4.9	5.6	6.2	6.9	7.7
270.....	2.2	2.7	3.1	3.6	4.2	4.7	5.4	6.0	6.7	7.4
280.....	2.2	2.6	3.0	3.5	4.0	4.6	5.2	5.8	6.4	7.1
290.....	2.1	2.5	2.9	3.4	3.9	4.4	5.0	5.6	6.2	6.9
300.....	2.0	2.4	2.8	3.3	3.7	4.3	4.8	5.4	6.0	6.7

Inclination correction—Continued.

Length of section in meters.	Difference of elevation in meters.									
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
70.....	31.5	34.6	37.8	41.1	....	....	....	....	....	....
80.....	27.6	30.2	33.1	36.0	39.1	42.2	45.6	49.0	....	....
90.....	24.5	26.9	29.4	32.0	34.7	37.6	40.5	43.6	46.7	50.0
100.....	22.0	24.2	26.4	28.8	31.2	33.8	36.4	39.2	42.0	45.0
110.....	20.0	22.0	24.0	26.2	28.4	30.7	33.1	35.6	38.2	40.9
120.....	18.4	20.2	22.0	24.0	26.0	28.2	30.4	32.7	35.0	37.5
130.....	17.0	18.6	20.3	22.1	24.0	26.0	28.0	30.2	32.3	34.6
140.....	15.7	17.3	18.9	20.6	22.3	24.1	26.0	28.0	30.0	32.1
150.....	14.7	16.1	17.6	19.2	20.8	22.5	24.3	26.1	28.0	30.0
160.....	13.8	15.1	16.5	18.0	19.5	21.1	22.8	24.5	26.3	28.1
170.....	13.0	14.2	15.6	16.9	18.4	19.9	21.5	23.1	24.7	26.5
180.....	12.2	13.4	14.7	16.0	17.4	18.8	20.2	21.8	23.4	25.0
190.....	11.6	12.7	13.9	15.2	16.5	17.8	19.2	20.6	22.1	23.7
200.....	11.0	12.1	13.2	14.4	15.6	16.9	18.2	19.6	21.0	22.5
210.....	10.5	11.5	12.6	13.7	14.9	16.1	17.4	18.7	20.0	21.9
220.....	10.0	11.0	12.0	13.1	14.2	15.4	16.6	17.8	19.1	20.5
230.....	9.6	10.5	11.5	12.5	13.6	14.7	15.8	17.0	18.3	19.6
240.....	9.2	10.1	11.0	12.0	13.0	14.1	15.2	16.3	17.5	18.7
250.....	8.8	9.7	10.6	11.5	12.5	13.5	14.6	15.7	16.8	18.0
260.....	8.5	9.3	10.2	11.1	12.0	13.0	14.0	15.1	16.2	17.3
270.....	8.2	9.0	9.8	10.7	11.6	12.5	13.5	14.5	15.6	16.7
280.....	7.9	8.7	9.4	10.3	11.2	12.1	13.0	14.0	15.0	16.1
290.....	7.6	8.3	9.1	9.9	10.8	11.7	12.6	13.5	14.5	15.5
300.....	7.3	8.1	8.8	9.6	10.4	11.3	12.1	13.1	14.0	15.0

82. Inclination corrections for 50-meter tape lengths.—

[Cor. = —.01h² — .000001h⁴.]

Difference in elevation.		Correction.	Difference in elevation.		Correction.	Difference in elevation.		Correction.
Meters.	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*
0.00	0.000	0.0	0.50	1.640	2.5	1.00	3.281	10.0
.01	.033	.0	.51	1.673	2.6	1.01	3.314	10.2
.02	.066	.0	.52	1.706	2.7	1.02	3.346	10.4
.03	.098	.0	.53	1.739	2.8	1.03	3.379	10.6
.04	.131	.0	.54	1.772	2.9	1.04	3.412	10.8
.05	.164	.0	.55	1.804	3.0	1.05	3.445	11.0
.06	.197	.0	.56	1.837	3.1	1.06	3.478	11.2
.07	.230	.0	.57	1.870	3.2	1.07	3.510	11.4
.08	.262	.1	.58	1.903	3.4	1.08	3.543	11.7
.09	.295	.1	.59	1.936	3.5	1.09	3.576	11.9
.10	.328	.1	.60	1.968	3.6	1.10	3.609	12.1
.11	.361	.1	.61	2.001	3.7	1.11	3.642	12.3
.12	.394	.1	.62	2.034	3.8	1.12	3.675	12.5
.13	.427	.2	.63	2.067	4.0	1.13	3.707	12.8
.14	.459	.2	.64	2.100	4.1	1.14	3.740	13.0
.15	.492	.2	.65	2.133	4.2	1.15	3.773	13.2
.16	.525	.3	.66	2.165	4.4	1.16	3.806	13.5
.17	.558	.3	.67	2.198	4.5	1.17	3.839	13.7
.18	.591	.3	.68	2.231	4.6	1.18	3.871	13.9
.19	.623	.4	.69	2.264	4.8	1.19	3.904	14.2
.20	.656	.4	.70	2.297	4.9	1.20	3.937	14.4
.21	.689	.4	.71	2.329	5.0	1.21	3.970	14.6
.22	.722	.5	.72	2.362	5.2	1.22	4.003	14.9
.23	.755	.5	.73	2.395	5.3	1.23	4.035	15.1
.24	.787	.6	.74	2.428	5.5	1.24	4.068	15.4
.25	.820	.6	.75	2.461	5.6	1.25	4.101	15.6
.26	.853	.7	.76	2.493	5.8	1.26	4.134	15.9
.27	.886	.7	.77	2.526	5.9	1.27	4.167	16.1
.28	.919	.8	.78	2.559	6.1	1.28	4.199	16.4
.29	.951	.8	.79	2.592	6.2	1.29	4.232	16.6
.30	.984	.9	.80	2.625	6.4	1.30	4.265	16.9
.31	1.017	1.0	.81	2.657	6.6	1.31	4.298	17.2
.32	1.050	1.0	.82	2.690	6.7	1.32	4.331	17.4
.33	1.083	1.1	.83	2.723	6.9	1.33	4.364	17.7
.34	1.115	1.2	.84	2.756	7.1	1.34	4.396	18.0
.35	1.148	1.2	.85	2.789	7.2	1.35	4.429	18.2
.36	1.181	1.3	.86	2.822	7.4	1.36	4.462	18.5
.37	1.214	1.4	.87	2.854	7.6	1.37	4.495	18.8
.38	1.247	1.4	.88	2.887	7.7	1.38	4.528	19.0
.39	1.280	1.5	.89	2.920	7.9	1.39	4.560	19.3
.40	1.312	1.6	.90	2.953	8.1	1.40	4,593	19.6
.41	1.345	1.7	.91	2.986	8.3	1.41	4.626	19.9
.42	1.378	1.8	.92	3.018	8.5	1.42	4.659	20.2
.43	1.411	1.8	.93	3.051	8.6	1.43	4.692	20.4
.44	1.444	1.9	.94	3.084	8.8	1.44	4.724	20.7
.45	1.476	2.0	.95	3.117	9.0	1.45	4.757	21.0
.46	1.509	2.1	.96	3.150	9.2	1.46	4.790	21.3
.47	1.542	2.2	.97	3.182	9.4	1.47	4.823	21.6
.48	1.575	2.3	.98	3.215	9.6	1.48	4.856	21.9
.49	1.608	2.4	.99	3.248	9.8	1.49	4.888	22.2

Inclination corrections for 50-meter tape lengths—Continued.

Difference in elevation.		Correction.	Difference in elevation.		Correction.	Difference in elevation.		Correction.
Meters.	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*
1.50	4.921	22.5	2.00	6.562	40.0	2.50	8.202	62.5
1.51	4.954	22.8	2.01	6.594	40.4	2.51	8.235	63.0
1.52	4.987	23.1	2.02	6.627	40.8	2.52	8.268	63.5
1.53	5.020	23.4	2.03	6.660	41.2	2.53	8.301	64.0
1.54	5.052	23.7	2.04	6.693	41.6	2.54	8.333	64.6
1.55	5.085	24.0	2.05	6.726	42.0	2.55	8.366	65.1
1.56	5.118	24.3	2.06	6.759	42.5	2.56	8.399	65.6
1.57	5.151	24.6	2.07	6.791	42.9	2.57	8.432	66.1
1.58	5.184	25.0	2.08	6.824	43.3	2.58	8.465	66.6
1.59	5.217	25.3	2.09	6.857	43.7	2.59	8.497	67.1
1.60	5.249	25.6	2.10	6.890	44.1	2.60	8.530	67.6
1.61	5.282	25.9	2.11	6.923	44.5	2.61	8.563	68.2
1.62	5.315	26.2	2.12	6.955	45.0	2.62	8.596	68.7
1.63	5.348	26.6	2.13	6.988	45.4	2.63	8.629	69.2
1.64	5.381	26.9	2.14	7.021	45.8	2.64	8.661	69.7
1.65	5.413	27.2	2.15	7.054	46.2	2.65	8.694	70.3
1.66	5.446	27.6	2.16	7.087	46.7	2.66	8.727	70.8
1.67	5.479	27.9	2.17	7.119	47.1	2.67	8.760	71.3
1.68	5.512	28.2	2.18	7.152	47.5	2.68	8.793	71.9
1.69	5.545	28.6	2.19	7.185	48.0	2.69	8.825	72.4
1.70	5.577	28.9	2.20	7.218	48.4	2.70	8.858	73.0
1.71	5.610	29.2	2.21	7.251	48.9	2.71	8.891	73.5
1.72	5.643	29.6	2.22	7.283	49.3	2.72	8.924	74.0
1.73	5.676	29.9	2.23	7.316	49.8	2.73	8.957	74.6
1.74	5.709	30.3	2.24	7.349	50.2	2.74	8.989	75.1
1.75	5.741	30.6	2.25	7.382	50.7	2.75	9.022	75.7
1.76	5.774	31.0	2.26	7.415	51.1	2.76	9.055	76.2
1.77	5.807	31.3	2.27	7.447	51.6	2.77	9.088	76.8
1.78	5.840	31.7	2.28	7.480	52.0	2.78	9.121	77.3
1.79	5.873	32.0	2.29	7.513	52.5	2.79	9.154	77.9
1.80	5.906	32.4	2.30	7.546	52.9	2.80	9.186	78.5
1.81	5.938	32.8	2.31	7.579	53.4	2.81	9.219	79.0
1.82	5.971	33.1	2.32	7.612	53.9	2.82	9.252	79.6
1.83	6.004	33.5	2.33	7.644	54.3	2.83	9.285	80.2
1.84	6.037	33.9	2.34	7.677	54.8	2.84	9.318	80.7
1.85	6.070	34.2	2.35	7.710	55.3	2.85	9.350	81.3
1.86	6.102	34.6	2.36	7.743	55.7	2.86	9.383	81.9
1.87	6.135	35.0	2.37	7.776	56.2	2.87	9.416	82.4
1.88	6.168	35.3	2.38	7.808	56.7	2.88	9.449	83.0
1.89	6.201	35.7	2.39	7.841	57.2	2.89	9.482	83.6
1.90	6.234	36.1	2.40	7.874	57.6	2.90	9.514	84.2
1.91	6.266	36.5	2.41	7.907	58.1	2.91	9.547	84.8
1.92	6.299	36.9	2.42	7.940	58.6	2.92	9.580	85.3
1.93	6.332	37.2	2.43	7.972	59.1	2.93	9.613	85.9
1.94	6.365	37.6	2.44	8.005	59.6	2.94	9.646	86.5
1.95	6.398	38.0	2.45	8.038	60.1	2.95	9.678	87.1
1.96	6.430	38.4	2.46	8.071	60.6	2.96	9.711	87.7
1.97	6.463	38.8	2.47	8.104	61.0	2.97	9.744	88.3
1.98	6.496	39.2	2.48	8.136	61.5	2.98	9.777	88.9
1.99	6.529	39.6	2.49	8.169	62.0	2.99	9.810	89.5

Inclination corrections for 50-meter tape lengths—Continued.

Difference in elevation.		Correction.	Difference in elevation.		Correction.	Difference in elevation.		Correction.
Meters.	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*
3.00	9.842	90.1	3.50	11.483	122.7	4.00	13.123	160.3
3.01	9.875	90.7	3.51	11.516	123.4	4.01	13.156	161.1
3.02	9.908	91.3	3.52	11.549	124.1	4.02	13.189	161.9
3.03	9.941	91.9	3.53	11.581	124.8	4.03	13.222	162.7
3.04	9.974	92.5	3.54	11.614	125.5	4.04	13.255	163.5
3.05	10.007	93.1	3.55	11.647	126.2	4.05	13.287	164.3
3.06	10.039	93.7	3.56	11.680	126.9	4.06	13.320	165.1
3.07	10.072	94.3	3.57	11.713	127.6	4.07	13.353	165.9
3.08	10.105	95.0	3.58	11.745	128.3	4.08	13.386	166.7
3.09	10.138	95.6	3.59	11.778	129.0	4.09	13.419	167.6
3.10	10.171	96.2	3.60	11.811	129.8	4.10	13.451	168.4
3.11	10.203	96.8	3.61	11.844	130.5	4.11	13.484	169.2
3.12	10.236	97.4	3.62	11.877	131.2	4.12	13.517	170.0
3.13	10.269	98.1	3.63	11.909	131.9	4.13	13.550	170.9
3.14	10.302	98.7	3.64	11.942	132.7	4.14	13.583	171.7
3.15	10.335	99.3	3.65	11.975	133.4	4.15	13.615	172.5
3.16	10.367	100.0	3.66	12.008	134.1	4.16	13.648	173.4
3.17	10.400	100.6	3.67	12.041	134.9	4.17	13.681	174.2
3.18	10.433	101.2	3.68	12.073	135.6	4.18	13.714	175.0
3.19	10.466	101.9	3.69	12.106	136.3	4.19	13.747	175.9
3.20	10.499	102.5	3.70	12.139	137.1	4.20	13.780	176.7
3.21	10.531	103.1	3.71	12.172	137.8	4.21	13.812	177.6
3.22	10.564	103.8	3.72	12.205	138.6	4.22	13.845	178.4
3.23	10.597	104.4	3.73	12.238	139.3	4.23	13.878	179.2
3.24	10.630	105.1	3.74	12.270	140.1	4.24	13.911	180.1
3.25	10.663	105.7	3.75	12.303	140.8	4.25	13.944	181.0
3.26	10.696	106.4	3.76	12.336	141.6	4.26	13.976	181.8
3.27	10.728	107.0	3.77	12.369	142.3	4.27	14.009	182.7
3.28	10.761	107.7	3.78	12.402	143.1	4.28	14.042	183.5
3.29	10.794	108.4	3.79	12.434	143.8	4.29	14.075	184.4
3.30	10.827	109.0	3.80	12.467	144.6	4.30	14.108	185.2
3.31	10.860	109.7	3.81	12.500	145.4	4.31	14.140	186.1
3.32	10.892	110.3	3.82	12.533	146.1	4.32	14.173	187.0
3.33	10.925	111.0	3.83	12.566	146.9	4.33	14.206	187.8
3.34	10.958	111.7	3.84	12.598	147.7	4.34	14.239	188.7
3.35	10.991	112.4	3.85	12.631	148.4	4.35	14.272	189.6
3.36	11.024	113.0	3.86	12.664	149.2	4.36	14.304	190.5
3.37	11.056	113.7	3.87	12.697	150.0	4.37	14.337	191.3
3.38	11.089	114.4	3.88	12.730	150.8	4.38	14.370	192.2
3.39	11.122	115.1	3.89	12.762	151.6	4.39	14.403	193.1
3.40	11.155	115.7	3.90	12.795	152.3	4.40	14.436	194.0
3.41	11.188	116.4	3.91	12.828	153.1	4.41	14.468	194.9
3.42	11.220	117.1	3.92	12.861	153.9	4.42	14.501	195.7
3.43	11.253	117.8	3.93	12.894	154.7	4.43	14.534	196.6
3.44	11.286	118.5	3.94	12.926	155.5	4.44	14.567	197.5
3.45	11.319	119.2	3.95	12.959	156.3	4.45	14.600	198.4
3.46	11.352	119.9	3.96	12.992	157.1	4.46	14.633	199.3
3.47	11.384	120.6	3.97	13.025	157.9	4.47	14.665	200.2
3.48	11.417	121.3	3.98	13.058	158.7	4.48	14.698	201.1
3.49	11.450	122.0	3.99	13.091	159.5	4.49	14.731	202.0

Inclination corrections for 50-meter tape lengths—Continued.

Difference in elevation.		Correction.	Difference in elevation.		Correction.	Difference in elevation.		Correction.
Meters.	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*
4.50	14.764	202.9	5.00	16.404	250.6	5.50	18.045	303.4
4.51	14.797	203.8	5.01	16.437	251.6	5.51	18.077	304.5
4.52	14.829	204.7	5.02	16.470	252.6	5.52	18.110	305.6
4.53	14.862	205.6	5.03	16.503	253.6	5.53	18.143	306.7
4.54	14.895	206.5	5.04	16.535	254.7	5.54	18.176	307.9
4.55	14.928	207.5	5.05	16.568	255.7	5.55	18.209	309.0
4.56	14.961	208.4	5.06	16.601	256.7	5.56	18.241	310.1
4.57	14.993	209.3	5.07	16.634	257.7	5.57	18.274	311.2
4.58	15.026	210.2	5.08	16.667	258.7	5.58	18.307	312.3
4.59	15.059	211.1	5.09	16.699	250.8	5.59	18.340	313.5
4.60	15.092	212.0	5.10	16.732	260.8	5.60	18.373	314.6
4.61	15.125	213.0	5.11	16.765	261.8	5.61	18.405	315.7
4.62	15.157	213.9	5.12	16.798	262.8	5.62	18.438	316.8
4.63	15.190	214.8	5.13	16.831	263.9	5.63	18.471	318.0
4.64	15.223	215.8	5.14	16.863	264.9	5.64	18.504	319.1
4.65	15.256	216.7	5.15	16.896	265.9	5.65	18.537	320.2
4.66	15.289	217.6	5.16	16.929	267.0	5.66	18.570	321.4
4.67	15.321	218.6	5.17	16.962	268.0	5.67	18.602	322.5
4.68	15.354	219.5	5.18	16.995	269.0	5.68	18.635	323.7
4.69	15.387	220.4	5.19	17.028	270.1	5.69	18.668	324.8
4.70	15.420	221.4	5.20	17.060	271.1	5.70	18.701	326.0
4.71	15.453	222.3	5.21	17.093	272.2	5.71	18.734	327.1
4.72	15.486	223.3	5.22	17.126	273.2	5.72	18.766	328.3
4.73	15.518	224.2	5.23	17.159	274.3	5.73	18.799	329.4
4.74	15.551	225.2	5.24	17.192	275.3	5.74	18.832	330.6
4.75	15.584	226.1	5.25	17.224	276.4	5.75	18.865	331.7
4.76	15.617	227.1	5.26	17.257	277.4	5.76	18.898	332.9
4.77	15.650	228.0	5.27	17.290	278.5	5.77	18.930	334.0
4.78	15.682	229.0	5.28	17.323	279.6	5.78	18.963	335.2
4.79	15.715	230.0	5.29	17.356	280.6	5.79	18.996	336.4
4.80	15.748	230.9	5.30	17.388	281.7	5.80	19.029	337.5
4.81	15.781	231.9	5.31	17.421	282.8	5.81	19.062	338.7
4.82	15.814	232.9	5.32	17.454	283.8	5.82	19.094	339.9
4.83	15.846	233.8	5.33	17.487	284.9	5.83	19.127	341.0
4.84	15.879	234.8	5.34	17.520	286.0	5.84	19.160	342.2
4.85	15.912	235.8	5.35	17.552	287.0	5.85	19.193	343.4
4.86	15.945	236.8	5.36	17.585	288.1	5.86	19.226	344.6
4.87	15.978	237.7	5.37	17.618	289.2	5.87	19.258	345.8
4.88	16.010	238.7	5.38	17.651	290.3	5.88	19.291	346.9
4.89	16.043	239.7	5.39	17.684	291.4	5.89	19.324	348.1
4.90	16.076	240.7	5.40	17.716	292.5	5.90	19.357	349.3
4.91	16.109	241.7	5.41	17.749	293.5	5.91	19.390	350.5
4.92	16.142	242.7	5.42	17.782	294.6	5.92	19.423	351.7
4.93	16.175	243.6	5.43	17.815	295.7	5.93	19.455	352.9
4.94	16.207	244.6	5.44	17.848	296.8	5.94	19.488	354.1
4.95	16.240	245.6	5.45	17.881	297.9	5.95	19.521	355.3
4.96	16.273	246.6	5.46	17.913	299.0	5.96	19.554	356.5
4.97	16.306	247.6	5.47	17.946	300.1	5.97	19.587	357.7
4.98	16.339	248.6	5.48	17.979	301.2	5.98	19.619	358.9
4.99	16.371	249.6	5.49	18.012	302.3	5.99	19.652	360.1

Inclination corrections for 50-meter tape lengths—Continued.

Difference in elevation.		Correction.	Difference in elevation.		Correction.	Difference in elevation.		Correction.
Meters.	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*	*Meters.*	*Feet.*	*mm.*
6.00	19.685	361.3	6.50	21.325	424.3	7.00	22.966	492.4
6.01	19.718	362.5	6.51	21.358	425.6	7.01	22.999	493.8
6.02	19.751	363.7	6.52	21.391	426.9	7.02	23.031	495.2
6.03	19.783	364.9	6.53	21.424	428.2	7.03	23.064	496.6
6.04	19.816	366.1	6.54	21.457	429.5	7.04	23.097	498.1
6.05	19.849	367.4	6.55	21.489	430.9	7.05	23.130	499.5
6.06	19.882	368.6	6.56	21.522	432.2	7.06	23.163	500.9
6.07	19.915	369.8	6.57	21.555	433.5	7.07	23.195	502.3
6.08	19.947	371.0	6.58	21.588	434.8	7.08	23.228	503.8
6.09	19.980	372.3	6.59	21.621	436.2	7.09	23.261	505.2
6.10	20.013	373.5	6.60	21.654	437.5	7.10	23.294	506.6
6.11	20.046	374.7	6.61	21.686	438.8	7.11	23.327	508.1
6.12	20.079	375.9	6.62	21.719	440.2	7.12	23.360	509.5
6.13	20.112	377.2	6.63	21.752	441.5	7.13	23.392	511.0
6.14	20.144	378.4	6.64	21.785	442.8	7.14	23.425	512.4
6.15	20.177	379.7	6.65	21.818	444.2	7.15	23.458	513.8
6.16	20.210	380.9	6.66	21.850	445.5	7.16	23.491	515.3
6.17	20.243	382.1	6.67	21.883	446.9	7.17	23.524	516.7
6.18	20.276	383.4	6.68	21.916	448.2	7.18	23.556	518.2
6.19	20.308	384.6	6.69	21.949	449.6	7.19	23.589	519.6
6.20	20.341	385.9	6.70	21.982	450.9	7.20	23.622	521.1
6.21	20.374	387.1	6.71	22.014	452.3	7.21	23.655	522.5
6.22	20.407	388.4	6.72	22.047	453.6	7.22	23.688	524.0
6.23	20.440	389.6	6.73	22.080	455.0	7.23	23.720	525.5
6.24	20.472	390.9	6.74	22.113	456.3	7.24	23.753	526.9
6.25	20.505	392.2	6.75	22.146	457.7	7.25	23.786	528.4
6.26	20.538	393.4	6.76	22.178	459.1	7.26	23.819	529.9
6.27	20.571	394.7	6.77	22.211	460.4	7.27	23.852	531.3
6.28	20.604	395.9	6.78	22.244	461.8	7.28	23.884	532.8
6.29	20.636	397.2	6.79	22.277	463.2	7.29	23.917	534.3
6.30	20.669	398.5	6.80	22.310	464.5	7.30	23.950	535.7
6.31	20.702	399.7	6.81	22.342	465.9	7.31	23.983	537.2
6.32	20.735	401.0	6.82	22.375	467.3	7.32	24.016	538.7
6.33	20.768	402.3	6.83	22.408	468.7	7.33	24.049	540.2
6.34	20.800	403.6	6.84	22.441	470.0	7.34	24.081	541.7
6.35	20.833	404.9	6.85	22.474	471.4	7.35	24.114	543.1
6.36	20.866	406.1	6.86	22.507	472.8	7.36	24.147	544.6
6.37	20.899	407.4	6.87	22.539	474.2	7.37	24.180	546.1
6.38	20.932	408.7	6.88	22.572	475.6	7.38	24.213	547.6
6.39	20.965	410.0	6.89	22.605	477.0	7.39	24.245	549.1
6.40	20.997	411.3	6.90	22.638	478.4	7.40	24.278	550.6
6.41	21.030	412.6	6 91	22.671	479.8	7.41	24.311	552.1
6.42	21.063	413.9	6.92	22.703	481.2	7.42	24.344	553.6
6.43	21.096	415.2	6.93	22.736	482.6	7.43	24.377	555.1
6.44	21.129	416.5	6.94	22.769	484.0	7.44	24.409	556.6
6.45	21.161	417.8	6.95	22.802	485.4	7.45	24.442	558.1
6.46	21.194	419.1	6.96	22.835	486.8	7.46	24.475	559.6
6.47	21.227	420.4	6.97	22.867	488.2	7.47	24.508	561.1
6.48	21.260	421.7	6.98	22.900	489.6	7.48	24.541	562.6
6.49	21.293	423.0	6.99	22.933	491.0	7.49	24.573	564.1
						7.50	24.606	565.7

83. Computation of Savannah to Norfolk traverse line.—

Section.	Date.	Dir. of meas.	Tape No.	Uncorrected length.		Temp.	Corrections.					Adopted length.
				Tape lengths.	Meters.		Temp.	Tape.	Set-up; setback.	Inclination.	Sea level.	
	1918.					°C.	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*
North (rail) to 20	May 11	F	552	20	1000	38.3	+0.0061	+0.0212	0.0000	−0.0401	−0.0226	1366.9858
20 to Douglas	...do...	F	552	7	350	39.4	+ .0024	− .0042	+17.0230			
Douglas to Woodford	May 13	F	552	67	3350	27.6	+ .0004	+ .0516	+ 5.1800	− .2150	− .0607	3354.9563
Woodford to Miller	...do...	F	552	28	1400	32.5	+ .0040	+ .0102	− 1.2111	− .1465	− .0273	1398.6293
Miller to 20	...do...	F	552	20	1000	30.9	+ .0020	+ .0077	+ .0430	− .1747	− .0413	2260.6737
20 to Miller A	May 16	F	552	25	1250	19.9	− .0053	+ .0168	+10.8255			
Miller A to Swansea A	...do...	F	552	10	500	22.1	− .0015	− .0108	+11.3940	− .0238	− .0089	511.3490
Swansea A to Swansea B	...do...	F	552	14½	725	23.7	− .0015	− .0060	− 1.8840	− .1337	− .0124	722.9624
Swansea B to 20	...do...	F	552	20½	1025	26.2	− .0007	+ .0140	− .1245	− .1332	− .0191	1187.7395
20 to Swansea C	...do...	F	552	3	150	28.7	+ .0001	− .0026	+13.0055			
Swansea C to Swansea D	...do...	F	552	6½	325	26.9	− .0001	− .0028	+ 3.8200	− .0673	− .0049	328.7449

84. Explanation of the computation above.—Some of the sections between stations are computed in two or more parts in the computation above, because the whole section was not measured in a single day and the temperatures for the different days vary enough to make a separate computation for each day's work desirable.

(*a*) The temperature correction is computed as follows:

$$\text{Temp. cor.} = (T - T_s) \times \text{temp. coef.} \times 50 \times \text{No. of tape lengths (see p. 34)},$$

in which T=the mean temperature for the section and T_s=the temperature of the tape at standardization (27°.4 C. for this tape). The temperature coefficient is the change in length per meter for each degree centigrade change in temperature. The temperature correction given in the certificate on page 34 is per tape length and must be divided by 50 to obtain the temperature coefficient.

(*b*) For the tape correction see the certificate of standardization below and the tape-standardization tables on page 36. The catenary correction is included in the tape correction, as the tapes are supported in the field in the same manner as when standardized.

(*c*) For the inclination correction, see page 24.

(*d*) The sea-level correction or the correction for reducing the length to sea level is computed by the formula,

$$\text{Sea level cor.} = \frac{Ah}{r},$$

in which A=the length of section in meters, uncorrected except for set-up or setback to the nearest meter, h=mean elevation of section to nearest meter (see p. 24) and r=mean radius of the earth. Log r is obtained from the tables on pages 55–60 of Special Publication No. 26. The arguments for use in these tables are obtained by estimating the mean latitude and azimuth for each part of the traverse line in which the various sections have the same general direction. For the computation above, log r was computed for that part of the traverse line extending from the Savannah River to Columbia, as the line is practically straight for that whole distance. Log r=6.80312.

85. Certificate of standardization (invar base tape No. 552.)—

DECEMBER 5, 1910.

Supported horizontally at 0, 25, and 50 meter points under tension of 15 kilograms:

$$\begin{array}{lll} (0 \text{ to } 50 \text{ m.}) = 50 \text{ m.} & -2.815 \text{ mm.} + (t-27.°4 \text{ C.}) & 0.0282 \text{ mm.} \\ (\text{probable errors}) & \pm 0.020 \text{ mm.} & \pm 0.0008 \text{ mm.} \end{array}$$

Supported horizontally at 0, 12.5, 25, 37.5, and 50 meter points under tension of 15 kilograms:

$$\begin{array}{lll} (0 \text{ to } 50 \text{ m.}) = 50 \text{ m.} & +0.113 \text{ mm.} + (t-27.°3 \text{ C.}) & 0.0282 \text{ mm.} \\ (\text{probable errors}) & \pm 0.019 \text{ mm.} & \pm 0.0008 \text{ mm.} \end{array}$$

Mass per meter=25.8 grams.

86. Additional computed values of tape corrections (invar base tape No. 552.)—

$$\Delta L=\frac{n}{24}\left(\frac{w}{t}\right)^2 l^3$$

ΔL=the amount the tape is shortened by supporting it at equidistant intervals instead of supporting it throughout.

n=number of sections into which the tape is divided by equidistant supports.

l=length of such section.

w=weight of tape per unit of length.

t=the applied tension.

Supported throughout under tension of 15 kilograms:

(0 to 50 m.)=50 m.+1.060 mm.+(t−27.°4 C.) 0.0282 mm.

Supported horizontally at 0 and 50 meter points under tension of 15 kilograms:

(0 to 50 m.)=50 m.−14.371 mm.+(t−27.°4 C.) 0.0282 mm.

87. To obtain the tape correction when a part of the tape is supported on stakes and the remainder is supported throughout, use combinations of the proper fractional parts of the corresponding corrections given above. For example, if the tape is supported horizontally at the 0 and 25 meter points and throughout from the 25 to 50 meter points under a tension of 15 kilograms, the tape correction is computed as follows:

Tape Cor.=½ (−2.815 mm.)+½ (+1.060 mm.)=−0.878 mm.

and the formula for the length becomes

(0 to 50 m.)=50 m.−0.878 mm.+(t−27.°4 C.) 0.0282 mm.

88. Temperature corrections, tape No. 552.—

[Cor.=+(t−27.°4 C.) 0.0000282 meters per tape length.]

Temperature.	Correction.	Temperature.	Correction.	Temperature.	Correction.	Proportional parts.		
°C.		°C.		°C.			28	29
0	−0.000773	15	−0.000350	30	+0.000073			
1	744	16	321	31	102			
2	716	17	293	32	130	1	3	3
3	688	18	265	33	158	2	6	6
4	660	19	237	34	186	3	8	9
5	631	20	209	35	214	4	11	12
6	603	21	180	36	243	5	14	14
7	575	22	152	37	271	6	17	17
8	547	23	124	38	299	7	20	20
9	519	24	96	39	327	8	22	23
10	491	25	68	40	355	9	25	26
11	462	26	40	41	384	10	28	29
12	434	27	−0.000011	42	412			
13	406	28	+0.000017	43	440			
14	−0.000378	29	+0.000045	44	468			
				45	+0.000496			

89. Tape corrections for tape No. 552 when supported throughout.—

Tape lengths.	Correction.	Tape lengths.	Correction.	Tape lengths.	Correction.	Tape lengths.	Correction.
	Meters.		*Meters.*		*Meters.*		*Meters.*
1	+0.0011	26	0.0276	51	0.0541	76	0.0806
2	.0021	27	.0286	52	.0551	77	.0816
3	.0032	28	.0297	53	.0562	78	.0827
4	.0042	29	.0307	54	.0572	79	.0837
5	.0053	30	.0318	55	.0583	80	.0848
6	.0064	31	.0329	56	.0594	81	.0859
7	.0074	32	.0339	57	.0604	82	.0869
8	.0085	33	.0350	58	.0615	83	.0880
9	.0095	34	.0360	59	.0625	84	.0890
10	.0106	35	.0371	60	.0636	85	.0901
11	.0117	36	.0382	61	.0647	86	.0912
12	.0127	37	.0392	62	.0657	87	.0922
13	.0138	38	.0403	63	.0668	88	.0933
14	.0148	39	.0413	64	.0678	89	.0943
15	.0159	40	.0424	65	.0689	90	.0954
16	.0170	41	.0435	66	.0700	91	.0965
17	.0180	42	.0445	67	.0710	92	.0975
18	.0191	43	.0456	68	.0721	93	.0986
19	.0201	44	.0466	69	.0731	94	.0996
20	.0212	45	.0477	70	.0742	95	.1007
21	.0223	46	.0488	71	.0753	96	.1018
22	.0233	47	.0498	72	.0763	97	.1028
23	.0244	48	.0509	73	.0774	98	.1039
24	.0254	49	.0519	74	.0784	99	.1049
25	0.0265	50	0.0530	75	0.0795	100	0.1060

90. Tape corrections for tape No. 552 for various methods of support.—

Tape lengths.	Correction, tape supported—						
	at 0, 25, and 50 m. points.	at 0, 12½, 25, 37½, and 50 m. points.	at 0, 25, 37½, and 50 m. points.[a]	at 0 and 25 m. points and throughout from 25 to 50 m.[b]	at 0, 12½, and 25 m. points and throughout from 25 to 50 m.[c]	at 0, 25, and 37½ m. points and throughout from 37½ to 50 m.[d]	at 0 and 50 m. points.
	Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*	*Meters.*
1	−0.0028	+0.0001	−0.0014	−0.0009	+0.0006	−0.0011	−0.0144
2	.0056	.0002	.0027	.0018	.0012		
3	.0084	.0003	.0041	.0026	.0018		
4	.0113	.0005	.0054	.0035	.0023		
5	.0141	.0006	.0068	.0044	.0029		
6	.0169	.0007	.0081	.0053	.0035		
7	.0197	.0008	.0095	.0061	.0041		
8	.0225	.0009	.0108	.0070	.0047		
9	.0253	.0010	.0122	.0079	.0053		
10	−0.0282	+0.0011	−0.0135	−0.0088	+0.0059		

[a] Equivalent to tape supported at 0, 12½, 25, and 50 meter points.
[b] Equivalent to tape supported at 25 and 50 meter points and throughout from 0 to 25 meters.
[c] Equivalent to tape supported at 25, 37½, and 50 meter points and throughout from 0 to 25 meters.
[d] Equivalent to tape supported at 12½, 25, and 50 meter points and throughout from 0 to 12½ meters.

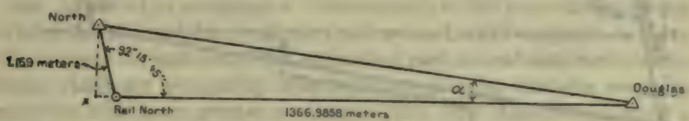

FIG. 2.—Diagram for projection computation, one offset station.

91. Projection computation, North to Douglas.—

(See fig. 2.)

log 7.169=0. 8554586
log sin 92° 15′ 45″=9. 9996613−10
log dist. North to X=0. 8551199

log 7.169=0. 8554586
log cos 92° 15′ 45″=8. 5963531−10
log dist. Rail North to X=9. 4518117

Dist. Rail North to X= 0. 2830 meters
Dist. Rail North to Douglas=1366. 9858 meters
Dist. Douglas to X=1367. 2688 meters

log. dist. North to X =0.8551199
log. dist. Douglas to X=3. 1358539
log tan α=7. 7192660−10
log sec. α=0. 0000060[a]
log dist. Douglas to X=3. 1358539
log dist. North to Douglas=3. 1358599
Dist. North to Douglas=1367. 2877 meters

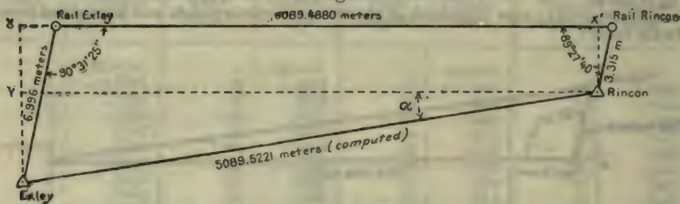

FIG. 3.—Diagram for projection computation, both stations offset on same side of track.

92. If both stations involved are offset from the measured line, a computation similar to the first half of the computation above must be made for each end of the line. The distance between the two "X" points can thus be obtained and will give the length of the base of the long, slender right triangle by which the final length between stations is computed. The short side of this right triangle is obtained by adding together the distances from the "X" points to the stations

[a] It is not necessary to take out the value of angle α. Find in the log tables the log tan α just computed, and then on the same page in the corresponding column and line under the heading of cosine will be found log cos α. The colog of this cosine is the log secant α desired. The logarithms of the cosine and secant change very slowly for such small angles and can be obtained readily with little interpolation.

in case the stations are on opposite sides of the track or by subtracting the smaller distance from the larger in case the stations are on the same side of the track. (See figs. 3 and 4.)

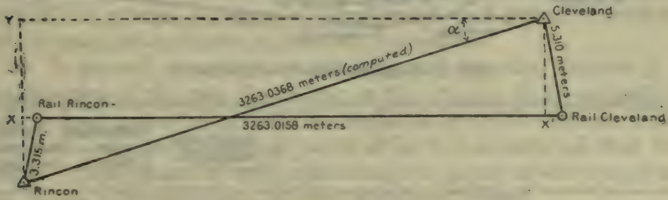

FIG. 4.—Diagram for projection computation, stations offset on opposite sides of track.

93. In making the projection computations it is very essential that a diagram similar to one of the figures 2 to 5 be made for each computation. Much confusion will thus be avoided and gross errors eliminated. As the offset distance is small as compared with the distance between stations, it is well in making these diagrams to exaggerate very considerably the distances at right angles to the track and also to exaggerate the angles when it is necessary for the sake of clearness.

Computation to close loops.

94. As stated in paragraph 4, it is desirable in hilly or rolling country where the railroad has numerous curves and short tangents to carry the azimuth through long lines, extending past several intermediate stations which are necessarily near together, in order that the resulting azimuth may have greater accuracy. The loop thus formed gives a good check on the angle measurements. It also gives a rough check on the distance measurements, for if an error has been made in the taping the departures or perpendiculars for the loop will not sum up to zero unless the error was made on a line very nearly parallel to the long line through which the azimuth is carried. The error will show up also in the position computations if they are made both through the long line and through the short lines.

95. The manner of computing the loop and making the projections to the main line is shown in the following computation. See also figure 5. The computation of the departures or perpendiculars mentioned in the paragraph above is made in the same manner as the computation of distance for the loop as shown in the table on the following page except that in column 4 log sin azimuth should be used in place of log cos azimuth. The sign of the function must be taken into account.

96. Computation of angle closure for loop.—

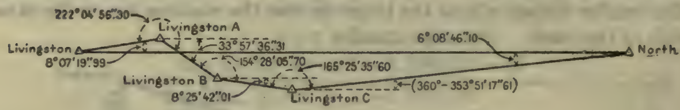

FIG. 5.—Diagram for loop computation.

	Angles and azimuths.			Correction for closure.	Final corrected seconds.
	°	′	″	″	″
Assumed azimuth Livingston-North	00	00	00.00	....	00.00
Angle at Livingston	− 8	07	19.99	−0.74	20.73
Azimuth Livingston-Livingston A	351	52	40.01	....	39.27
Azimuth Livingston A-Livingston	171	52	40.01	....	39.27
Angle at Livingston A	222	04	56.30	−0.74	55.56
Azimuth Livingston A-Livingston B	33	57	36.31	....	34.83
Azimuth Livingston B-Livingston A	213	57	36.31	....	34.83
Angle at Livingston B	154	28	05.70	−0.74	04.96
Azimuth Livingston B-Livingston C	8	25	42.01	....	39.79
Azimuth Livingston C-Livingston B	188	25	42.01	....	39.79
Angle at Livingston C	165	25	35.60	−0.74	34.86
Azimuth Livingston C-North	353	51	17.61	....	14.65
Azimuth North-Livingston C	173	51	17.61	....	14.65
Angle at North	6	08	46.10	−0.75	45.35
Azimuth North-Livingston	180	00	03.71	....	00.00
Error of closure			03.71	....	....
Error of closure per angle			0.74	....	....

97. Computation of distance for loop.—

Section.	Length.	Azimuth.[a]			Log cos azimuth.	Log length.	Log projected length.	Projected length.
	Meters.	°	′	″				*Meters.*
Livingston .. Livingston A.	1247.9212	351	52	39.27	9.9956214	3.0961872	3.0918086	1235.4028
Livingston A. Livingston B.	1074.4132	33	57	34.83	9.9187803	3.0311713	2.9499516	891.1516
Livingston B. Livingston C.	1152.3746	8	25	39.79	9.9952848	3.0615936	3.0568784	1139.9304
Livingston C. North.......	5536.1025	353	51	14.65	9.9974966	3.7432041	3.7407007	5504.2823
Computed distance Livingston-North								8770.7671
Log distance Livingston-North								3.9430376

[a] These are the azimuths computed in the preceding computation. They are referred to the line Livingston-North, which was assumed to have the azimuth 0° 00′ 00.00″, and the convergence of the meridians was not taken into account. Consequently they are not true azimuths.

GENERAL INSTRUCTIONS FOR SECONDARY TRAVERSE.

98. Secondary traverse will be used in those areas where secondary triangulation would ordinarily be carried on except for the configuration of the ground, presence of heavy woods, and extensive swamps which make triangulation excessively expensive.

99. In general, secondary triangulation and secondary traverse or a combination of the two, depending on the country to be controlled, will be used instead of primary triangulation or precise traverse when the distance between terminal points of the line or arc is less than 150 miles. These classes of work must always be joined at each end of an arc or line with previously adjusted horizontal control.

100. The probable error of the length of a line of secondary traverse should, in general, be not greater than 1 part in 25 000. This accuracy will be obtained if the error of closure in position is less than about 1 part in 10 000 of the distance run.

101. The general instructions for precise traverse will apply to secondary traverse, except where they conflict with the following considerations.

102. One measurement will be made of each section of a line of traverse with a 50-meter invar tape under the same conditions as obtained during standardization, except as to temperature. It may be found desirable to read and record the temperature for each tape length in order to keep count of the number of tape lengths. Otherwise the temperature will be read and recorded three times on each section—once near the beginning, once near the end, and once near the middle of the section. These readings are necessary to avoid uncertainty in case one temperature is erroneously read or recorded.

103. The temperature may be read from only one thermometer; but, should this be done, the thermometer should be carefully examined and be compared with a standard thermometer once each day in order to detect any break in the thread of mercury which might have occurred.

104. When measuring along a country road, the forward end of the tape may be marked by a nail driven into the ground or by a wooden peg, on which the end of the tape may be indicated by a small nail driven into the peg. A piece of paper laid on the ground and weighted down, by a stone or earth, near the peg or nail will enable the rear tape man to find the nail or peg easily.

105. If any part of the tape is unsupported, a note to this effect should be made in the record book and a correction for sag or catenary will be computed and applied when the office computation is made.

106. For measurements along a rail of a railroad no inclinations will be computed for separate tape lengths where the slope is approximately

the same from one end of the section to the other. Under this condition the inclination correction for the distance will be taken from the inclination correction table which follows. There will be computed for each tape length the inclination correction for portions of a section which are measured over stakes. This is necessary because the grade is frequently steep when measuring from a point of tangency on a railroad to the station at the end of the section.

107. Inclination correction (see p. 25).—

Distance in meters.	Difference of elevation in meters.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
100	5	20	45											
200	2	10	22	40	62	90								
300		7	15	27	42	60	82	107	135					
400		5	11	20	31	45	61	80	101	125	151	180		
500			9	16	25	36	49	64	81	100	121	144	169	196
600			8	13	21	30	41	53	67	83	101	120	141	163
700			6	11	18	26	35	46	58	71	86	103	121	140
800				10	16	23	31	40	51	63	76	90	106	123
900				9	14	20	27	36	45	56	67	80	94	109
1000				8	12	18	24	32	40	50	60	72	84	98
1100					11	16	22	29	37	45	55	65	77	89
1200					10	15	20	27	34	42	50	60	70	82
1300						14	19	25	31	38	46	55	65	75
1400						13	18	23	29	36	43	51	60	70
1500							16	21	27	33	40	48	56	65
1600							15	20	25	31	38	45	53	61
1700								19	24	29	36	42	50	58
1800								18	22	28	34	40	47	54
1900								17	21	26	32	38	44	52
2000									20	25	30	36	42	49

Distance in meters.	Difference of elevation in meters.												
	15	16	17	18	19	20	21	22	23	24	25	26	27
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
500	225												
600	187	213	241	270									
700	161	183	206	231	258	286	315						
800	141	160	181	203	226	250	276	303	331	360			
900	125	142	161	180	201	222	245	269	294	320	347	376	405
1000	112	128	144	162	180	200	220	242	264	288	312	338	364
1100	102	116	131	147	164	182	200	220	240	262	284	307	331
1200	94	107	120	135	150	167	184	202	220	240	260	282	304
1300	86	98	111	125	139	154	170	186	203	222	240	260	280
1400	80	91	103	116	129	143	157	173	189	206	223	241	260
1500	75	85	96	108	120	133	147	161	176	192	208	225	243
1600	70	80	90	101	113	125	138	151	165	180	195	211	228
1700	66	75	85	95	106	118	130	142	156	169	184	199	214
1800	62	71	80	90	100	111	122	134	147	160	174	188	202
1900	59	67	76	85	95	105	116	127	139	152	164	178	192
2000	56	64	72	81	90	100	110	121	132	144	156	169	182

Inclination correction—Continued.

Distance in meters.	Difference of elevation in meters.												
	28	29	30	31	32	33	34	35	36	37	38	39	40
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1000	392	420	450	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1100	356	382	409	437	465	495	.....	.....	.....	.....	.....	.....	.....
1200	327	350	375	400	427	454	482	510	540	.....	.....	.....	.....
1300	302	323	346	370	394	419	445	471	498	527	555	585	.....
1400	280	300	321	343	366	389	413	438	463	489	516	543	571
1500	261	280	300	320	341	363	385	408	432	456	481	507	533
1600	245	263	281	300	320	340	361	383	405	428	451	475	500
1700	231	247	265	283	301	320	340	360	381	403	425	447	471
1800	218	234	250	267	284	302	321	340	360	380	401	422	444
1900	206	221	237	253	269	287	304	322	341	360	380	400	421
2000	196	210	225	240	256	272	289	306	324	342	361	380	400

108. In taking the inclination correction from the tables the difference in elevation of the two points of tangency of a section can be obtained from the Y leveling over the stakes at the ends of a section. The record should show clearly what are the differences in elevation between the ends of the section and the points of tangency, and there should be no doubt whatever as to the sign of each difference. These differences applied to the difference in elevation of the ends of the section as furnished by the precise leveling will give the difference in elevation of the points of tangency, which is one of the arguments in obtaining the correction from the table. The other argument is the distance between the tangent points. In most cases the grade corrections obtained from the table will be too small, owing to irregularities in the slope of the line, but the error will in nearly all cases be less than 1 part in 100 000, and therefore may be neglected.

109. Should the grade change decidedly in a section, the distance of the change or changes from one of the ends of the section should be noted in the record of tape measurement, and the slope may be measured by a small transit or theodolite. The correction will be

$$D\ (1-\cos A),$$

where D is the measured distance and A is the angle of inclination.

The following table gives values of $1-\cos A$ for various slopes.

110. Factors for inclination correction.—

[Correction=D (1−cos A).]

Angle of inclination.	1−cos A.	Angle of inclination.	1−cos A.	Angle of inclination.	1−cos A.	Angle of inclination.	1−cos A.
° ′		° ′		° ′		° ′	
0 00	0.0000000	0 50	0.0001058	1 40	0.0004230	2 30	0.0009518
0 01	0.0000000	51	1100	41	4315	31	9645
02	0002	52	1144	42	4401	32	9773
03	0004	53	1188	43	4488	33	0.0009902
04	0007	54	1234	44	4576	34	0.0010032
05	0011	55	1280	45	4664	35	0163
06	0015	56	1327	46	4753	36	0294
07	0021	57	1375	47	4843	37	0427
08	0027	58	1423	48	4934	38	0560
09	0034	59	1473	49	5026	39	0694
0 10	0.0000042	1 00	0.0001523	1 50	0.0005119	2 40	0.0010829
11	0051	01	1574	51	5212	41	0965
12	0061	02	1626	52	5307	42	1101
13	0072	03	1679	53	5402	43	1239
14	0083	04	1733	54	5498	44	1377
15	0095	05	1788	55	5595	45	1516
16	0108	06	1843	56	5692	46	1656
17	0122	07	1899	57	5791	47	1797
18	0137	08	1956	58	5890	48	1939
19	0153	09	2014	59	5991	49	2081
0 20	0.0000169	1 10	0.0002073	2 00	0.0006092	2 50	0.0012224
21	0187	11	2133	01	6194	51	2369
22	0205	12	2193	02	6296	52	2514
23	0224	13	2254	03	6400	53	2660
24	0244	14	2317	04	6505	54	2806
25	0264	15	2380	05	6610	55	2954
26	0286	16	2444	06	6716	56	3103
27	0308	17	2508	07	6823	57	3252
28	0332	18	2574	08	6931	58	3402
29	0356	19	2640	09	7040	59	3553
0 30	0.0000381	1 20	0.0002708	2 10	0.0007149	3 00	0.0013705
31	0407	21	2776	11	7260		
32	0433	22	2845	12	7371		
33	0461	23	2914	13	7483		
34	0489	24	2985	14	7596		
35	0518	25	3057	15	7710		
36	0548	26	3129	16	7824		
37	0579	27	3202	17	7940		
38	0611	28	3276	18	8056		
39	0644	29	3351	19	8173		
0 40	0.0000677	1 30	0.0003427	2 20	0.0008291		
41	0711	31	3503	21	8410		
42	0746	32	3581	22	8530		
43	0782	33	3659	23	8650		
44	0819	34	3738	24	8772		
45	0857	35	3818	25	8894		
46	0895	36	3899	26	9017		
47	0935	37	3980	27	9141		
48	0975	38	4063	28	9266		
49	1016	39	4146	29	9391		

111. When measuring distances of a secondary traverse along a country road, slopes may be measured as angles of inclination with a small transit or theodolite, or the differences in elevation of the tape ends may be obtained by a single line of ordinary leveling. In order that there may be no uncertainty as to the identification of the tape ends, it may be advisable to have the leveling follow just behind the measuring party.

112. When measuring over a country road where the ground is nearly level or where the slopes are low with very small changes in grade, it will not be necessary to determine the difference in elevation of the ends of each tape length. Under such conditions it will be best to measure inclinations as angles.

113. A second measurement must be made of each section of a secondary traverse with a 300 or 200 foot tape. This measurement made with a tape of a different unit from that of the tape used in the first measurement will make it reasonably certain that no tape length has been dropped or added in the first measurement and will also guard against a blunder in measuring a set-up. The second measurement is made only as a check, and no grade, temperature, sag, or other corrections will be made to the distance measured. A second check measurement should be made with the foot tape if the first check measurement does not agree within one part in 1500 with the measurement, uncorrected for grade, made with the meter tape. If the error was made in the meter-tape measurement, a second measurement should be made with that tape. The record must indicate clearly the accepted length.

Measurement of angles.

114. In general, the angles of the traverse will be measured with a 7-inch theodolite, using the method of repetitions. The requisite accuracy will probably be obtained if the angle is measured by 6 repetitions of the angle and 6 repetitions of the explement of the angle. The telescope should be reversed in the middle of the set to eliminate the effect of the collimation error. If the angles are measured with a direction theodolite, three or four measures, with the initial readings equally spaced on the circle, will be sufficient. The angle should be measured clockwise from the back station.

115. The greatest care should be used to make sure that the pole on which the angle observations are made is straight, accurately centered over the station, and vertical. If the line is of such length that the pole can not be distinctly seen, one face of the signal pole or of any target used should be placed at right angles to the line of sight to avoid the effect of phase.

Azimuth stations.

116. Azimuth stations on secondary traverse lines will be established at intervals of from 15 to 20 traverse stations. These azimuths should have an accuracy represented by a probable error not greater than $\pm 1.''5$. This accuracy can probably be obtained by making double the number of observations that is used in measuring a horizontal angle of the secondary traverse. Instructions for azimuth observations will be found on page 14.

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